REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave Blank)	2. REPORT DATE August 13, 1997	3. REPORT TYPE AND DATES COVERED Interim (July 1, 1996 – August 12, 1997

4. TITLE AND SUBTITLE High Volume Communication Channels (A mathematical investigation)	5. FUNDING NUMBERS AFOSR Grant F49620-96-1-0328

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9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) AFOSR 110 Duncan Avenue, Suite B115 Bolling AFB, DC 20332-0001	10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

Time-discrete one and two-dimensional sequences and arrays with perfect autocorrelation functions are studied. Such sequences find applications in signal processing and as aperture functions for electromagnetic and acoustic imaging. Two dimensional perfect arrays are also applicable in 2-D synchronization and time-frequency coding. Mathematical tools from algebraic number theory, representation theory and group theory are employed to investigate the theory of their existence leading to new families of these arrays and some generalizations thereof.

DTIC QUALITY INSPECTED

14. SUBJECT TERMS Sequences, arrays, correlation			15. NUMBER OF PAGES 3
			16. PRICE CODE –

17. SECURITY CLASSIFICATION OF REPORT U	18. SECURITY CLASSIFICATION OF THIS PAGE U	19. SECURITY CLASSIFICATION OF ABSTRACT U	20. LIMITATION OF ABSTRACT UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-1
298-102

Progress report on

AFOSR grant F49620-96-1-0328
High volume communication channels :
A mathematical investigation
for the period covering July, 1996 to August 1997

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1. Objectives:

Time-discrete one and two-dimensional sequences and arrays with
perfect autocorrelation functions are studied. Such sequences
find applications in signal processing and as aperture functions
for electromagnetic and acoustic imaging. Two dimensional perfect
arrays are also applicable in 2-D synchronization and time-
frequency coding. Mathematical tools from algebraic number
theory, representation theory and group theory are employed to
investigate the theory of their existence leading to new families
of these arrays and some generalizations thereof.

2. Status of effort:

Periodic sequences and multidimensional arrays whose entries
are either 0, 1 and -1 or the complex fourth roots of unity
are studied. These sequences/arrays with low autocorrelation
values are useful in reliable synchronization problems. Some new
constructions of a class of such sequences have been obtained.
A few structure theorems for these mathematical objects have also
been proved, in a joint work with Ma and Voss. Another joint work
with Seberry has resulted in classifying the existence status of
periodic ternary sequences (i.e. with entries 0, 1 and -1) all
of whose out-of-phase autocorrelations are zero. This work
assumes the period of the sequences to be the number of points on
a projective plane of certain finite order (an extremal case for
this class of sequences). As a bye-product of the methods, we
were able to construct a new class of nested row-column designs
based on a Galois Field, and these designs are useful in
statistical design of experiments.

3. Accomplishments:

Periodic sequences with entries plus or minus one all but one
of whose autocorrelation coefficients are zero were studied by
Wolfmann. Using their equivalence to certain nice subsets in
a cyclic group whose order equals the period of the corresponding
sequence (these subsets are called divisible difference sets),
we obtain sequences of period 8,12 and 28. Further structure
theorems using the factorization of ideals in a suitable
algebraic number field are also proven. The theory developed in
this paper [1] could be used for other types of sequences and
arrays. This joint work with Ma and Voss has appeared in the
Journal of Algebra.

In [2], (a joint work with Ma), we characterize those abelian

groups which admit a McFarland difference set of order 81. These difference sets are variations of the well-known Hadamard difference sets which are equivalent to perfect binary arrays. Our methods do not make use of the widely made assumption known as "self-conjugacy". (This roughly means that the complex conjugation fixes the prime ideal factors of the principal ideal generated by the order of the corresponding difference set). We thus are able to fill two missing entries in Kopilovich's table. (Incidentally Kopilovich is a Ukranian engineer who is writing up a monograph in this area that connects radar problems and "my" kind of mathematics. Our results will be cited in his book.) This paper [2] has been submitted to the journal Designs, Codes and Cryptography.

A square matrix W of order n with entries from $\{0, -1, +1\}$ satisfying $W W^t = k I_n$ is said to be a weighing matrix of order n with weight k. If the underlying matrix is also circulant, we therefore get a perfect ternary sequence of period n. Using very interesting facts about finite fields, we provide a construction of a family of circulant matrices of weight $33t$ and weight 25, for each positive integer t. Consequently we fill a missing entry in the CRC handbook (Section on weighing matrices by Craigen). While not a single matrix of order 33 and weight 25 was known before, we actually constructed a circulant one, to the surprise of experts in this field. Our new matrices also give a rise to a new class of orthogonal designs. This paper [3] has been accepted by the Journal of Combinatorial Designs.

In [4] Seberry and the P.I. investigate circulant weighing matrices of various weights whose order equal the number of points on a finite projective plane. This is an extremal case and the investigation is very theoretical. We have settled the existence question in orders upto 25. This paper has been submitted to the Australasian Journal of Combinatorics.

In [5], (joint work with Balasubramanian and Evans), we point out the connection between quadratic starters in a finite field and a class of nested row-column designs. As a consequence we provide an infinite class of such designs, generalizing a few sporadic examples obtained earlier by others. This paper has been accepted by the Journal of Combinatorics and Combinatorial Computing.

4. Publications:

1. On a class of almost perfect sequences, (with S.L.Ma and N.J.Voss), J. Algebra. 192, 641-650(1997).

2. Abelian difference sets without self-conjugacy, (with S.L.Ma), submitted to Designs, Codes and Cryptography.

3. New weighing matrices of weight 25, Journal of Combinatorial Designs, 5, 1-5(1997).

4. Circulant weighing matrices, (With Jennifer Seberry), submitted to Australasian J. Combinatorics.

5. A new family of nested row-column designs, (with Balasubramanian and A.B.Evans), to appear in Journal of Combinatorial Mathematics and Combinatorial Computing.

Personnel supported

Jeffrey Linthicum, Graduate research assistant

Conference Presentations
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1. Invited lecture at the third International Conference of Combinatorics
and Statistics at Portland, Maine, July 1997

2. Keynote addresse at the International conference on Combinatorics,
May 1997, Hefei, China

3. Invited colloquium at the University of Hong Kong, May 1997

4. Invited colloquium at the Mathematical Institute, Madras, India,
June 1997

Honors

I have been invited to write a chapter on Difference sets and its relation
to Communication Engineering by Wiley Publishers. This 40 to 50 page article
will be one chapter of an encyclopedia they are publishing on Computational
Engineering.